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Lethality of Bursting Munitions and Their Effect on Survivability

by Natalie Eberius, Patrick Gillich, and Kathleen Doonan

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Lethality of Bursting Munitions and Their Effect on Survivability

Natalie Eberius, Patrick Gillich, and Kathleen Doonan
Survivability/Lethality Analysis Directorate, ARL

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14. ABSTRACT
The distances at which mounted personnel in military vehicles and dismounted personnel can survive blast threat detonations is of interest. Zones described in terms of area of effect and range provide a technical basis for hazard standoff distances (i.e., distances at which explosive ordnance disposal teams can safely operate). Current standoff requirements are often based on limited test and simulation data, with feedback observed in the field providing a significant contribution. These lethality zone estimates support system requirement definitions, input to tactics, techniques and procedures, and risk assessment. This report details the capability of the MUVES-S2 model to simulate both threat and target interactions to construct improved vulnerability zones detailing lethality and survivability in terms of measures of personnel injury. Empirical data sets support threat characterization that describe ballistic behavior and projectile properties as well as ballistic material modeling of vehicle componentry, armor, and personnel protective equipment.

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bursting munitions, MAIS, ORCA, MUVES-S2

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1. Purpose

This report describes a methodology which uses U.S. Army Research Laboratory Survivability/Lethality Analysis Directorate tools and techniques to characterize the lethality of fragments from bursting munitions and their effect on personnel survivability. Current operations have generated the need to understand the expected injuries resulting from such threats. Bursting munitions are a recurring threat in today's urban battlefield. It is important to capture and understand the zonal injury footprint of these munitions to properly equip and educate current forces.

2. Injury Mechanisms

Typical bursting munitions generate several different types of injury mechanisms. The fragmentation standoff requirement for hazards for typical bursting munitions is significantly greater than the distances where other injury mechanisms are a factor. For this reason, methodology often focuses on the fragmentation effects of the bursting munition. However, at closer ranges, other injury mechanisms generate additional lethality concerns. At these ranges, injuries may be from blast overpressure, thermal energy, and blunt trauma. Injuries due to blast overpressure may include eardrum damage and lung damage. Injuries due to thermal energy like skin burn may also occur. Depending on the size and orientation of debris, there is the potential for blunt trauma.

3. Characterization of Bursting Munitions

Empirical data quantify the fragmentation and blast characteristics of the bursting munition threat. These data are acquired through a specialized test referred to as an arena test. Arena testing consists of an array of witness panels surrounding the threat in order to collect and capture fragments from the munitions. The panels can be set at varying distances and arranged in various collection patterns (e.g., horseshoe and square) in order to characterize the effect at given ranges. Depending on the test requirements, varying materials may be used to construct these panels. An initial understanding of the threat aids in the arrangement of the panels. Effective arena design uses this understanding to capture the maximum number of fragments without compromising the arena. An example of an arena test setup is pictured in figure 1. Velocity screens and pressure transducers are instrumented to record fragment velocities and

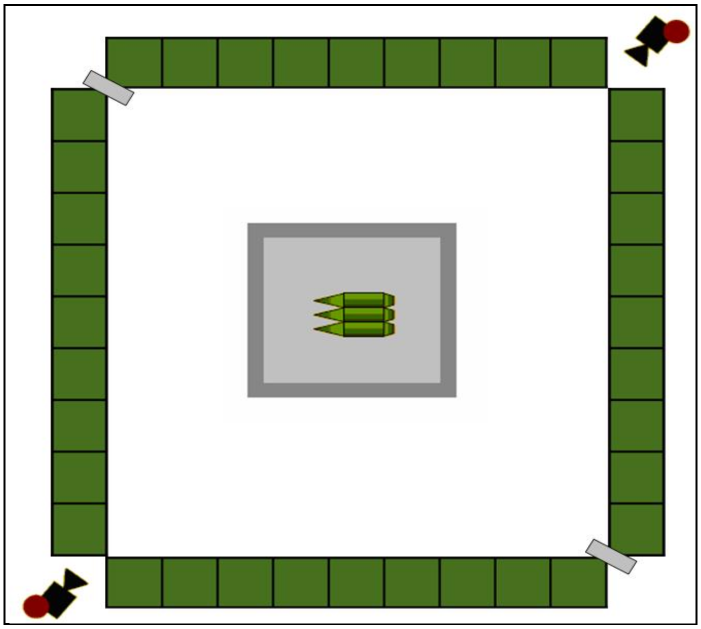

Figure 1. Example arena test setup.

pressure data, respectively. High-speed cameras may be placed in the surrounding area to augment the collected data. The fragment masses, numeric densities, and peak velocities measured by electronic means are collected from incremental zones orientated relative to the munition axis. The fragment distribution is processed in accordance with standard testing procedures. A comprehensive report is constructed and includes blast overpressure measurements, velocity data, photographic evidence, fragment photographs, and fragment distribution. A statistical characterization of the fragmenting threat environment is also constructed into a standardized format referred to as Z-data format. Z-data contain the fragmentation in terms of fragment number, mass, velocity, and zonal distribution. The Z-data are then used as input for vulnerability/lethality models such as MUVES-S2.

4. Methodology for Modeling Bursting Munitions

The MUVES-S2 model is a stochastic, component-level survivability/vulnerability/lethality software suite that simulates the effects of indirect- and direct-fire munitions against modeled targets. MUVES-S2 has a long history of use and acceptance in the evaluation of vehicle and personnel vulnerability. Figure 2 depicts the inputs required and pertinent outputs generated in MUVES-S2 analysis. MUVES-S2 incorporates the Operational Requirement-based Casualty Assessment (ORCA) model as its preferred personnel assessment model. MUVES-S2 with embedded ORCA provides the U.S. Department of Defense with a standard computer simulation platform for evaluating effectiveness of munitions and missiles and the survivability and vulnerability of personnel, aircraft, missiles, and ground systems.

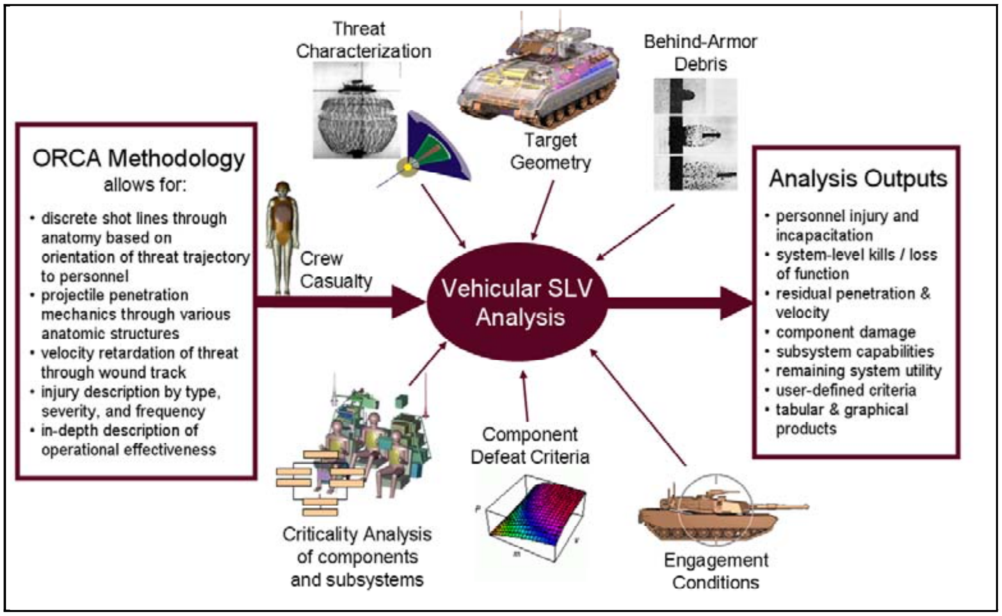

Figure 2. Inputs and outputs of the MUVES-S2 model with embedded ORCA.

Personnel inside vehicles or in the open are modeled using the ORCA man geometry. Personnel can be fitted with personal protective equipment (PPE) and articulated into various postures. Any known or prototypical PPE can be modeled given the geometric profile and ballistic capabilities. PPE can include flexible armor (i.e., vest), helmets, and hard plates.

A MUVES-S2 threat input file contains a description of the initial conditions of the threat in terms of its physical characteristics such as mass, velocity, length, and diameter. The threat is represented from Z-data containing fragment distribution which consists of numbers of fragments in a predefined set of mass classes and polar zones around the burst point. For a bursting munition analysis, each threat is detonated at a specific burst point in the target description's coordinate system. A percentage of fragments from the detonation will intersect with the target geometry, and the resulting ballistic effects will be assessed. Threat paths that intersect crew are evaluated using ORCA, and subsequent injuries are modeled.

5. ORCA Methodology

ORCA is a high-resolution computerized human vulnerability model that can be used to assess the impact of various casualty-causing insults on personnel. ORCA determines the type, severity, and frequency of injuries sustained by crew as well as the percent reduction in human capability from impacting fragments. Furthermore, ORCA includes improved methodology and enhanced capabilities compared to Sperrazza-Kokinakis and ComputerMan methodologies. Some of these improvements include a more precise anatomical representation, the ability to map injuries to physical and cognitive impairment, an evaluation of basic human capability

requirements to postinjury capabilities, a calculation of operational casualty metrics, and an accommodating methodology for improvements. The ORCA code has been reviewed by peers in the medical and biological fields and the U.S. Army and Navy services. They found the code to be adequate in producing injury, impairment, and operational casualty results within the documented model limitations.

ORCA classifies each computed penetrating injury using the Abbreviated Injury Scale – 1985 Revision (AIS-85), which is a standard measure of individual anatomical injury. AIS is an anatomically-based, consensus-derived, international injury scoring system that classifies injury by body region and its relative severity on a six-point ordinal scale.

Injury severity scoring systems provide the necessary analytical tools to accurately characterize the medical injury and injury severity with respect to survivability. ORCA calculates several summary severity trauma metrics that may be used to characterize the combined effects from multiple wounds as well as multiple injuries in a wound tract. One of these injury metrics is the maximum abbreviated injury scale (MAIS). This score classifies injury severity on the basis of the single injury having the greatest AIS severity level. Examples of MAIS levels are outlined in table 1.

Table 1. MAIS levels.

MAIS	Injury Level	Type of Injury
0	No injury	None
1	Minor	Superficial
2	Moderate	Reversible injuries; medical attention required
3	Serious	Reversible injuries; hospitalization required
4	Severe	Reversible injuries; not fully recoverable without care
5	Critical	Nonreversible injuries; not fully recoverable, even with care
6	Maximal	Nearly unsurvivable

6. Analysis of Bursting Munitions

MUVES-S2 with embedded ORCA is used to evaluate lethality of bursting munitions in terms of injury to personnel within target geometry. The lethality footprint of a bursting munition is obtained through the use of target arrays. In a typical analysis, a planar grid of cells is constructed, and each target in the array is evaluated given a detonation. An example of this target array is shown in figure 3, and an example of the elements in the grid plot is shown in figure 4. The characterization of the munition is described where the parameters of mass, velocity, shape factor, and trajectory angle are subjected to statistical variability. Another parameter that can be varied is the position of the target within the cell. This process allows the

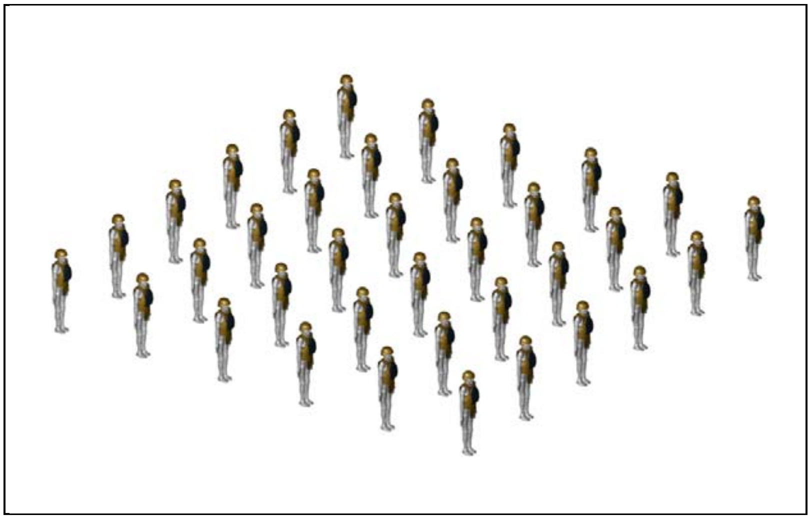

Figure 3. Typical target array.

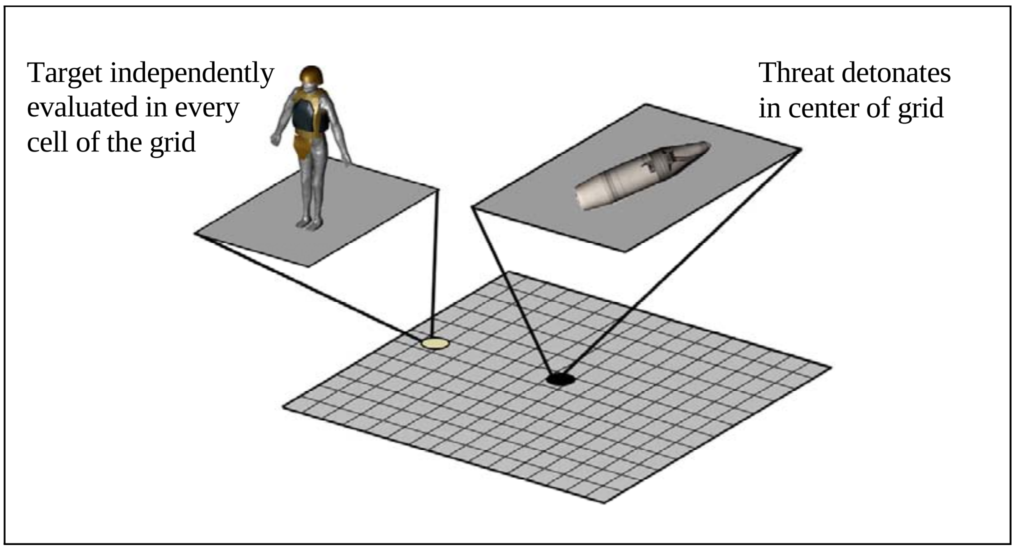

Figure 4. Elements of a bursting munition grid plot.

model to produce a distribution of burst results and a lethality footprint of the munition against various target geometries (e.g., a dismounted Soldier, other personnel, and crew inside of vehicle).

The output from these types of analyses can be displayed in contour plots where the metric can vary depending on the focus of the particular analysis. Some of the more common types of metrics are MAIS, probability of a specific MAIS level, number of hits to a particular personnel target, and number of hits to particular body regions. An example plot is shown in figure 5. This plot depicts model results of a bursting munition detonation from the grid space center and resultant effects on the target array of dismounted Soldiers. Each dismounted Soldier in the array is independently evaluated for every cell.

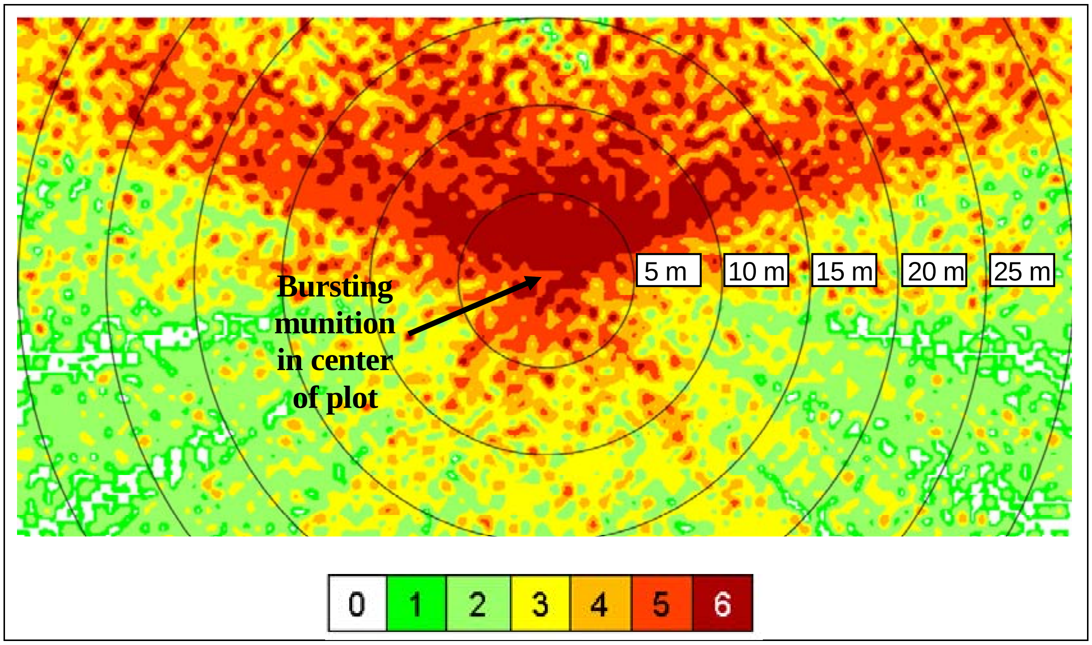

Figure 5. MAIS contour plot for bursting munition against a dismounted Soldier array.

In addition to generating plots which represent the bursting munitions' lethality in terms of effect on personnel injury, more specific information about the dismounted Soldier can be produced. Figure 6 illustrates specific details about the effects of a single detonation on a single cell in the grid space. In this example, the MAIS of the dismounted Soldier was 5 (critical injury) and, therefore, the cell that represents this location is color coded accordingly. The trajectories of all the fragments that caused injury can be modeled to help understand the behavior of the threat. Injuries can then be mapped to the surface geometry where the threat trajectories intersect the body. The impact locations and areas of influence can be visualized in three dimensions and color coded according to the MAIS level received. These analysis capabilities can demonstrate the utility of body armor systems and vehicular armor systems designed to protect against the lethal effects of bursting munitions. The comparison of armor systems can be easily measured and quantified to support performance measures and tradeoff analyses. These analyses can assist in understanding areas where protection provided by vehicular and body armors influences survivability.

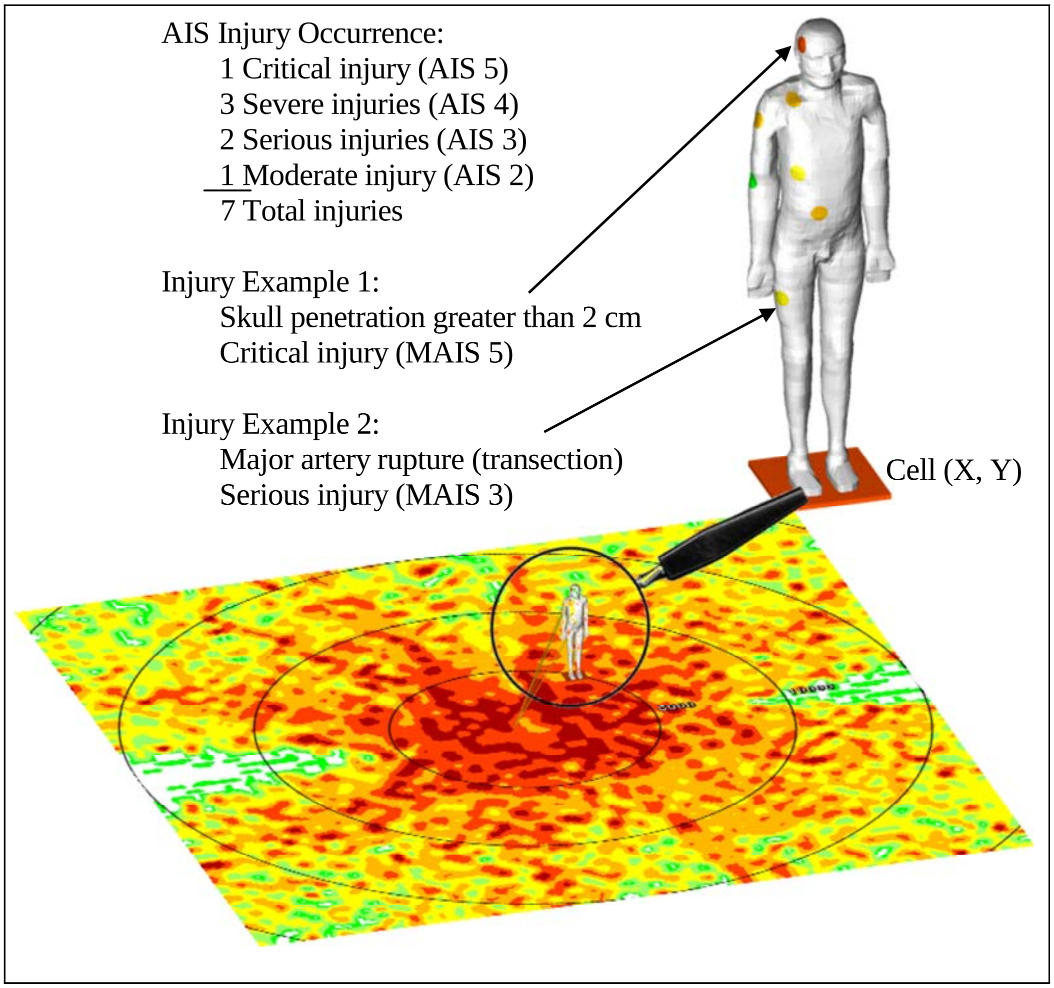

Figure 6. MAIS contour plot highlighting a dismounted Soldier on a single cell.

7. Conclusion

Penetrating fragment effects due to bursting munitions have become an increasingly important issue in the urban battlefield. The coupling of arena test data and modeling and simulation provides an improvement to the benefits of stand-alone arena testing. MUVES-S2 can effectively model threat fragmentation, fly-out, and the corresponding effect on personnel in various target environments. The use of modeling and simulation to generate lethality footprint plots for various artillery munition systems is a capability available with ORCA embedded in MUVES-S2. This capability supports the quantification of vulnerability zones described in terms of injury severity. The understanding offered by these zones provides standoff distances where personnel and military systems can continue the mission while maintaining a high probability of survivability on the battlefield.

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